AD-A176 308

RESEARCH MEMORANDUM

SUBPOPULATION DIFFERENCES IN EQUATING COMPUTERIZED ADAPTIVE AND PAPER-AND-PENCIL VERSIONS OF THE ASVAB

Peter H. Stoloff

DTIC
SELECTED
JAN 3 0 1987
E

A Division of **CNA** Hudson Institute

CENTER·FOR·NAVAL·ANALYSES

FILE COPY

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION / AVAILABILITY OF REPORT
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE	Approved for Public Release. Distribution Unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S) CRM 86-151	5. MONITORING ORGANIZATION REPORT NUMBER(S)

6a. NAME OF PERFORMING ORGANIZATION Center for Naval Analyses	6b. OFFICE SYMBOL (If applicable) CNA	7a. NAME OF MONITORING ORGANIZATION Commandant of the Marine Corps (Code RDS)
6c. ADDRESS (City, State, and ZIP Code) 4401 Ford Avenue Alexandria, Virginia 22302-0268		7b. ADDRESS (City, State, and ZIP Code) Headquarters, Marine Corps Washington, D.C. 20380
8a. NAME OF FUNDING / ORGANIZATION Office of Naval Research	8b. OFFICE SYMBOL (If applicable) ONR	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER N00014-83-C-0725

8c. ADDRESS (City, State, and ZIP Code) 800 North Quincy Street Arlington, Virginia 22217	10. SOURCE OF FUNDING NUMBERS			
	PROGRAM ELEMENT NO. 65153M	PROJECT NO. C0031	TASK NO.	WORK UNIT ACCESSION NO.

11. TITLE (Include Security Classification)

Subpopulation Differences in Equating Computerized Adaptive and Paper-and-Pencil Versions of the ASVAB

12. PERSONAL AUTHOR(S)
Peter H. Stoloff

13a. TYPE OF REPORT Final	13b. TIME COVERED FROM TO	14. DATE OF REPORT (Year, Month, Day) June 1986	15. PAGE COUNT 48

16. SUPPLEMENTARY NOTATION

17.	COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	AFQT (Armed forces qualification test), Aptitude tests, ASVAB (Armed services vocational
			aptitude battery), CAT (computerized adaptive test), Computer applications, Enlistment
			qualification, Factor analysis, Human factors, Mathematical analysis, PP (paper and pencil),
			Scoring, Subpopulations, Tables (data), Test methods, Test scores

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Computerized adaptive test (CAT) and paper-and-pencil (PP) ASVAB scores are equated in several subpopulations to determine if racial minorities, females, nonhigh school graduates, or those lacking experience using computers would be at a disadvantage if CAT rather that PP scores were used for selection. Equating is generally independent of population group.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified	
22a. NAME OF RESPONSIBLE INDIVIDUAL Lt.Col. G. W. Russell	22b. TELEPHONE (Include Area Code) (202) 694-3491	22c. OFFICE SYMBOL RDS-40

DD FORM 1473, 84 MAR   83 APR edition may be used until exhausted

All other editions are obsolete.   SECURITY CLASSIFICATION OF THIS PAGE

18 August 1986

MEMORANDUM FOR THE DISTRIBUTION LIST

Subj: Center for Naval Analyses Research Memorandum 86-151

Encl: (1)   CNA Research Memorandum 86-151, "Subpopulation
              Differences in Equating Computerized Adaptive and
              Paper-and-Pencil Versions of the ASVAB," Jun 1986

1.   Enclosure (1) is forwarded as a matter of possible interest.

2.   The Department of Defense may implement a computerized adaptive
testing (CAT) version of the Armed Services Vocational Aptitude Battery
(ASVAB) in the near future.   Equity requires that the transition from
paper-and-pencil ASVAB to CAT-ASVAB not penalize any gender, racial,
educational, or computer-experience subgroup.   This Research Memorandum
reports analysis on this issue.

William H. Sims
Director
Marine Corps Manpower
and Training Program

Distribution List:
Reverse Page

Accession For

NTIS GRA&I   X
DTIC TAB   ☐
Unannounced   ☐
Justification_____

By_____
Distribution/

Availability Codes

Dist   Avail and/or
        Special

A-1

DTIC
COPY
INSPECTED

Subj: Center for Naval Analyses Research Memorandum 86-151

Distribution List
SNDL
A1   ASSTSECNAV MRA
A1   DASN – MANPOWER
A6   HQMC MPR
        Attn: Deputy Chief of Staff for Manpower (2 copies)
        Attn: Director, Personnel Procurement Division (2 copies)
        Attn: Director, Manpower Plans and Policy Division (2 copies)
        Attn: Director, Personnel Management Division (2 copies)
A6   HQMC TRNG
A6   HQMC RD&S
E3D1   CNR
E3D5   NAVPERSRANDCEN
        Attn: Director, Manpower and Personnel Laboratory
        Attn: Technical Library
FF38   USNA
        Attn: Nimitz Library
FF42   NAVPGSCOL
FF44   NAVWARCOL
FJA1   COMNAVMILPERSCOM
FJB1   COMNAVCRUITCOM
FT1   CNET
V12   CG MCDEC

OPNAV
OP-01
OP-13

Other
CAT-ASVAB Working Group (12 copies)

SUBPOPULATION DIFFERENCES IN EQUATING COMPUTERIZED ADAPTIVE AND PAPER-AND-PENCIL VERSIONS OF THE ASVAB

Peter H. Stoloff

Marine Corps Operations Analysis Group
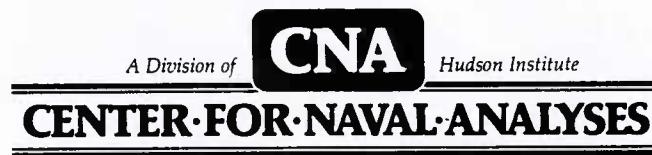
ABSTRACT

Computerized adaptive test (CAT) and paper-and-pencil (PP) ASVAB scores are equated in several subpopulations to determine if racial minorities, females, nonhigh school graduates, or those lacking experience using computers would be at a disadvantage if CAT rather that PP scores were used for selection. Equating is generally independent of population group.

EXECUTIVE SUMMARY

The Department of Defense (DOD) plans to introduce a computerized version of the Armed Services Vocational Aptitude Battery (ASVAB). To maintain continuity of enlistment standards, scores on the computerized adaptive test (CAT) and the paper-and-pencil (PP) version of the test must be interchangeable, and the proportion of examinees who qualify for enlistment should be the same for both versions of the test. The process by which tests are made interchangeable is called "equating." If CAT scores do not equate to PP scores in a similar manner for males and females, for example, then one of these subpopulations could be at a disadvantage.

This research memorandum compares the equating of CAT to PP ASVAB subtests and aptitude composites in various subpopulations — gender, race, education, and computer experience. The data used were previously collected from a joint service sample of recruits. Examinees completed a questionnaire focusing on computer experience, ease of taking the CAT, and other "human factors" variables. The results generally indicate that subpopulation effects are small and not likely to be a problem during the Accelerated CAT-ASVAB Program (ACAP), when the CAT will be equated to the PP ASVAB. Findings are summarized below.

HUMAN FACTORS VARIABLES AND CAT

The correlations between test scores and questionnaire items, such as those reflecting examinees' experience with computers and difficulty with taking the CAT, were relatively independent of test modality. Those lacking experience with computers tended to have low scores on both the CAT and PP versions of the subtests.

SUBTEST LEVEL EQUATING

Equating was generally independent of gender, education, and computer experience. Subjectively meaningful differences were noted, however, with respect to race for the Numerical Operations (NO), Auto Information (AI), and Math Knowledge (MK) subtests. These differences, on the order of two to three ASVAB standard score points, are in such a direction as to favor minorities on the AI and MK subtests and to the disadvantage of minorities on the NO subtest. Since NO is part of the Armed Forces Qualification Test

(AFQT), minorities could also be disadvantaged by one to two AFQT percentile points.

APTITUDE COMPOSITES

Only two composites were studied. No meaningful subpopulation differences were observed for the Clerical (CL) score. Small differences were noted for the Electronics (EL) score that would tend to favor minorities.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

The Department of Defense (DOD) plans to introduce a computerized version of the Armed Services Vocational Aptitude Battery (ASVAB). Initial use of the DOD computerized adaptive test (CAT) is expected to begin soon in a few locations as the Accelerated CAT-ASVAB Program (ACAP). To maintain continuity of enlistment standards, scores on the CAT and the paper-and-pencil (PP) versions of the test must be interchangeable. One requisite for interchangeability is that the proportion of examinees who qualify for enlistment be the same for both versions of the test. Interchangeability implies that for a given PP test score, the equivalent CAT score is the same for different demographic groups.

The process by which the scores for one version of the test are interchanged or made equal to those for the other is referred to as "equating." Differences in the equating transformation for two subpopulations could lead to inequities in the selection process. For example, suppose a PP Armed Forces Qualification Test (AFQT) score of 21 is required for selection. If the equivalent CAT AFQT score for one subpopulation is 18, versus 21 for the overall population, then about 3 percent more individuals in the subpopulation tested with the CAT would not qualify for enlistment using the conversion table for the overall population. These same individuals, however, would qualify for enlistment with the PP test.

A previous study [1] examined subpopulation differences in equating CAT to PP scores for the Word Knowledge (WK) and Arithmetic Reasoning (AR) ASVAB subtests. The results indicated only small differences (no more than 1.5 ASVAB standard score points) in the equating for racial and educational subpopulations. This research memorandum expands on the previous work by examining the entire battery of subtests and by comparing equatings for additional subpopulations.

DATA

Using data collected in an earlier study, equipercentile equating procedures are used to equate CAT to PP ASVAB subtest scores in several subpopulations. The data used were collected as part of a joint armed services study to validate an early version of the CAT [2]. In that study, the CAT scores were validated against training grades. Both CAT and PP ASVAB

retest data (ASVAB forms 8, 9, or 10) were collected during initial skill training from about 7,000 recruits representing all of the armed services. The PP and CAT tests were administered back-to-back in counterbalanced order with a short intervening rest period. The CAT data include all subtests—General Science (GS), Arithmetic Reasoning (AR), Word Knowledge (WK), Paragraph Comprehension (PC), Numerical Operations (NO), Coding Speed (CS), Auto Information (AI), Shop Information (SI),[1] Math Knowledge (MK), Mechanical Comprehension (MC), and Electronics Information (EI). The PP data include only those retest scores required for selection into the recruit's military occupational specialty (MOS). This typically numbered from three to five tests per individual.

The CAT item pool consisted of about 200 items per subtest. The items were calibrated by the Navy Personnel Research and Development Center on a sample of about 2,500 applicants per item using LOGIST II [3].

The speeded tests, Numerical Operations (NO) and Coding Speed (CS), were administered by computer but conventionally scored as number correct during the original data collection. These subtests were then rescored as number correct per unit time; that is, $4 \times$ number correct/testing time (seconds). This scoring method is consistent with that to be used in the ACAP; it tends to increase the variability at the high end of the score continuum because some examinees finish the test before the time limit. Figures 1 and 2 show the relationship between number correct and the "rate" scores for the NO and CS subtests. The rate scores for the speeded tests are used later in the equating.

ANALYTICAL PROCEDURES

Factor Analysis of Questionnaire

Examinees were given a questionnaire on the ease of responding to the computerized test (see appendix A). One question asked if the examinee had ever used a computer before. About 40 percent of the 2,396 respondents answered "no" to this question. For the purpose of this study, those with no

---

1. In the CAT test, the PP subtest Auto and Shop Information (AS) is divided into the two subtests AI and SI. In the equating, both the CAT AI and SI subtests are equated to the PP AS subtest.
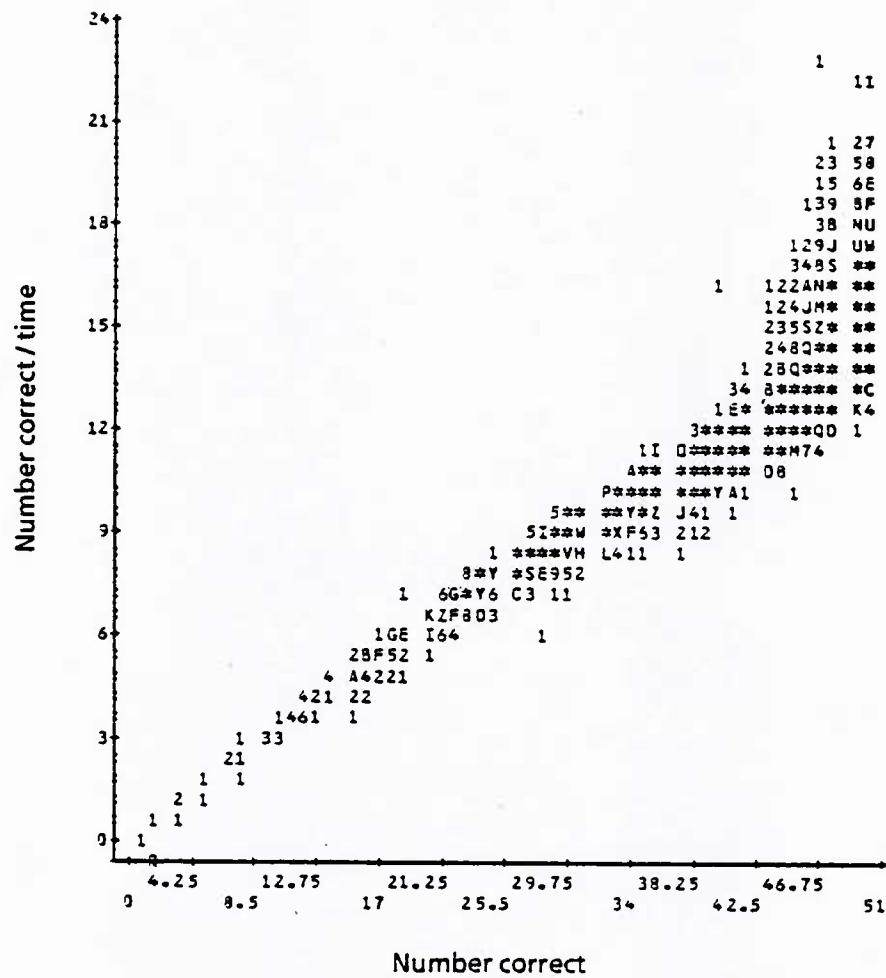
NOTE: Symbols indicate frequency of examinees per coordinate, where 1-Z represents 1-35, and * represents a frequency greater than 35.

FIG. 1: PLOT OF CAT NO SUBTEST: NUMBER CORRECT vs. NUMBER CORRECT / TIME
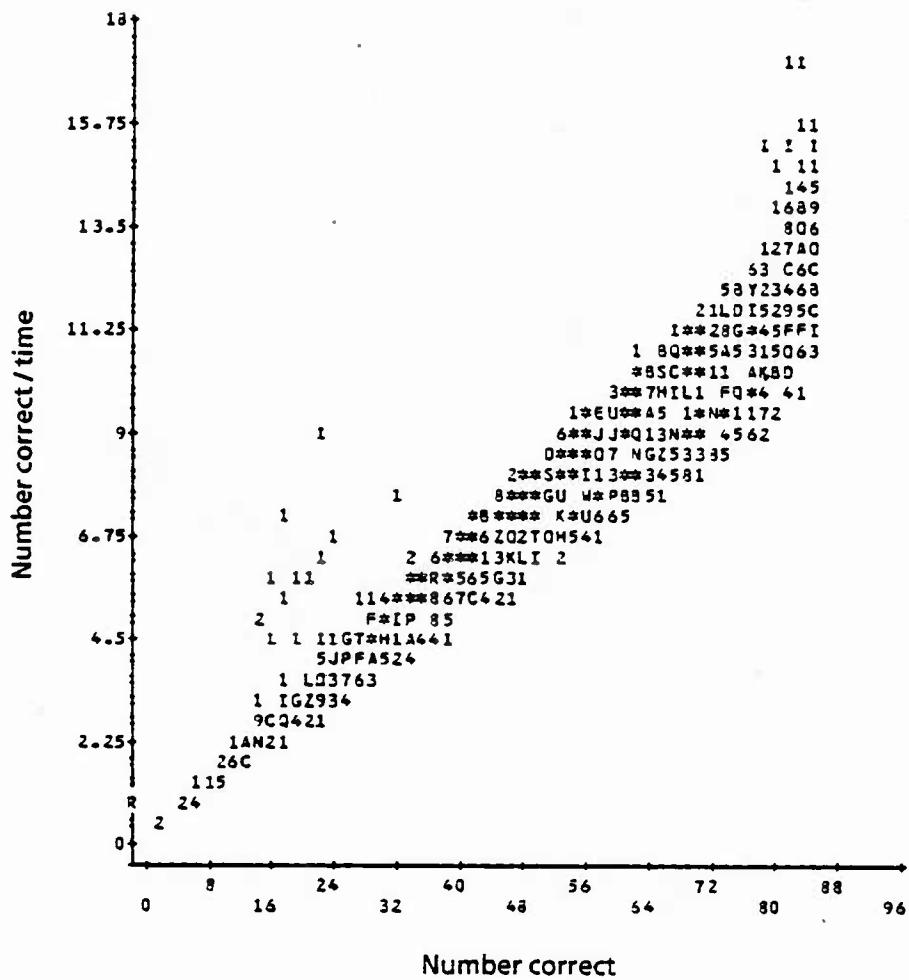
NOTE: Symbols indicate frequency of examinees per coordinate, where 1-Z represents 1-35, and * represents a frequency greater than 35.

FIG. 2: PLOT OF CAT CS SUBTEST: NUMBER CORRECT vs. NUMBER CORRECT / TIME

computer experience were used to define a "no computer experience" subpopulation.

Other subpopulations contrasted are gender, race, and education. The number of examinees from each subpopulation that had both CAT and PP ASVAB scores for the same subtests varied widely.

Responses to the questionnaire were used to determine "human factors" associated with the examinees' perceptions of the effects of the computer mode of test administration on test response. PP and CAT scores were then related to the factor scores to determine if perceptions about computer versus PP mode of test administration, called modality, were related to observed test scores.

Equating

Equipercentile equating, using analytic three-point moving average smoothing, was employed to equate the CAT to the PP tests. CAT scores, although originally estimated in the "theta" metric, were linearly transformed to a scale with a mean of 50 and a standard deviation of 10. These transformed scores were rounded to the nearest integer. This transformation was necessary for forming a discrete frequency distribution, as required by the computer software used to perform the equating. The result is a scale with unit intervals corresponding to one-tenth of a standard deviation of the original theta metric. After equating, the CAT scores were linearly transformed back to their original metric of mean zero and unit variance.

Aptitude Composites

Two aptitude composites, Electronics (EL) and Clerical (CL), were constructed from the CAT and PP data. These were chosen on the basis of adequacy of sample sizes in the available subpopulations. The CAT composites were built from the sum of equated subtest scores scaled to the 1980 reference population; that is, the CAT subtest scores were first equated to the appropriate PP subtest scores, then, these equated subtest scores were added and linearly transformed to the 1980 metric. The composites constructed in this manner were:

$$EL = MK + EI + GS + AR$$

$$CL = WK + PC + NO + CS \ .$$

RESULTS

Factor Analysis of Questionnaire

The questionnaire was composed of 32 items. Responses were quantified as shown in appendix A. The correlations were then factored by the Principal Components method, using an iterative procedure to estimate communalities [4]. Table 1 shows the resulting communalities. The communalities are conservative estimates of the reliability of the responses to the questionnaire.

Five interpretable factors, accounting for 32 percent of the total variance, emerged from the analysis. These factors were orthogonally rotated to produce the factor pattern shown in table 1. (Note that only those factor loadings greater than 0.25 are shown.)

The first factor, named "ease of use," is dominated by such items as "enjoyed taking the test on a computer" and "made corrections easily." Not enjoying the computer testing mode was associated with being uncomfortable with the rate of item presentation, not understanding the instructions for taking the different subtests and difficulty in correcting responses. Of particular interest is whether such difficulties in taking the CAT were reflected in the test scores. This issue is examined in detail later.

The second factor has to do with difficulty in reading the visual display. (See questions 7 and 8 in appendix A.) The magnitude of the factor loadings suggests that difficulty in reading the display was due to all the reasons enumerated in question 8 of appendix A (size of letters, font, spacing, contrast, and glare). About 10 percent of the respondents reported having difficulty with the display.

The third factor could be labeled an "annoyance factor." The items defining this factor have to do with the ease of using the keyboard and the noise level of the computer. Responses to these items were also related to feeling "uneasy" with the test and inability to change answers.

The fourth factor was composed of two similiarly worded items (questions 11 and 27) concerning eyestrain. Failure of these items to load on the "visual display" factor suggests that having difficulty with the visual display does not always lead to eyestrain.

TABLE 1

QUESTIONNAIRE FACTOR ANALYSIS RESULTS

	VARIMAX factor					
Item[a]	(1) Enjoy/ease of use	(2) Visual display	(3) Key-board	(4) Eye-strain	(5) Computer experience	Communality
ENJOY	.62					.43
CVSPPD	− .52					.36
UNSTDST	.50					.26
EASECOR	.47					.27
INSCLR	.43					.21
NOTIMES	.37					.20
RUSHED	.34					.19
CONFUS	− .28					.18
LAYOUT	.26					.14
READQ		− .75			..	.63
SIZE		.65				.44
TYPE		.58				.34
SPACE		.58				.35
CONTRAST		.50				.28
GLARE		.39				.21
PRESKEY		.68				.49
LOCKEY			.64			.43
NOISE			.62			.44
UNEASY	− .32		.42			.32
NOTCH	− .34		.38			.34
IMPERS			.37			.16
TIRED1				.88		.80
TIRED2				.83		.75
USEDC					.64	.45
USEDT					.55	.35
NEEDPI					− .52	.31
NEEDCI			.28		− .43	.27
SCNRATE					.41	.23
Percentage of total variance (Unrotated factor)	11.7	6.0	5.6	4.8	4.2	

a. See appendix A for the meanings of these mneumonics.

The last factor concerns the experience of examinees in using computers. Those who had not used a computer before indicated that they had never used a typewriter and had greater need for both the proctor's and the computer's instructions in order to take the test. Those with computer experience did not need help.

The effect these factors may have had on test scores is explored by forming factor scores from the questionnaire responses and correlating them to both the CAT and the PP ASVAB scores. Factor scores were formed as a weighted composite of the items comprising the factor. The weights were determined by a regression method that uses the questionnaire item inter-correlations to represent correlations among items, and the factor loadings to represent correlations between each item and the hypothetical factor [4]. A significant CAT-factor score correlation, in the absence of a PP-factor score correlation, would indicate the presence of a modality of test administration effect. Significant correlations for both CAT and PP scores with the factors would indicate that ability, as measured by the ASVAB subtest, is the determinant of the factor. For example, suppose a significant positive correlation is observed between "computer experience" and the CAT score for a particular subtest. If the PP score also correlated positively with the experience factor, the result could be interpreted to indicate that more able examinees (as measured by the subtest) tend to have more experience than less able examinees. In the absence of a correlation between the factor and the PP score, the interpretation would be that lack of experience with computers leads to lower CAT scores, but does not effect PP scores.

Table 2 shows the correlations between the five factor scores and the CAT and PP ASVAB subtest scores. Mean test scores for those with no computer experience and those with experience are also shown. The correlations between a given factor and ASVAB test score tends to be about the same for CAT and PP scores. For the most part, the correlations tend to be low.

There is no evidence of a modality effect associated with experience with computers. The differences in mean PP and CAT subtest scores across prior experience groups was, in most cases, statistically significant and except for the AS and EI group, in favor of those with computer experience. In the absence of a modality effect, this indicates that those having used computers prior to taking the CAT tend to be more able examinees. What remains to be determined is whether CAT equates to PP in a similar manner for those with and without prior computer experience.

TABLE 2

FACTOR, TEST SCORE CORRELATIONS

| | Factor | | | | | Subtest mean | |
| | (1)
Ease/like | (2)
Visual | (3) | (4) | (5)
Computer | Computer
experience | |
Subtest	CAT	display	Keyboard	Eyestrain	experience	No	Yes
GS (N = 523)							
PP	−0.009	−0.008	0.075	0.005	0.268[a]	55.11	57.19
CAT	0.016	−0.027	0.055	0.038	0.286[a]	0.64	0.86
AR (N = 661)							
PP	0.115[a]	−0.140[a]	0.033	0.021	0.227[a]	51.68	53.83
CAT	0.118[a]	−0.094	0.048	0.020	0.226[a]	0.53	0.69
WK (N = 1377)							
PP	0.073[a]	−0.067	0.090[a]	0.009	0.226[a]	50.44	52.09
CAT	0.043	−0.072[a]	0.115[a]	−0.008	0.230[a]	0.34	0.48
PC (N = 1377)							
PP	0.062	−0.068	0.070[a]	0.045	0.178[a]	48.69	50.18
CAT	0.021	−0.062	0.122[a]	0.033	0.196[a]	0.33	0.45
NO (N = 1025)							
PP	0.017	−0.071	0.081[a]	0.059	0.209[a]	52.44	54.55
CAT	0.050	0.045	0.154[a]	−0.021	0.260[a]	11.39	12.37
CS (N = 680)							
PP	−0.019	−0.040	0.133[a]	−0.060	0.140[a]	51.38	52.97
CAT	−0.046	−0.001	0.148[a]	−0.090	0.162[a]	8.56	9.06
AI (N = 735)							
PP (AS)[b]	0.068	0.020	0.038	0.031	0.022	56.04	55.55
CAT	0.048	0.052	0.066	0.052	−0.024	0.35	0.29
MK (N = 470)							
PP	−0.007	−0.002	0.042	0.003	0.253[a]	51.99	54.90
CAT	−0.009	−0.033	0.024	−0.014	0.237[a]	0.68	0.86
MC (N = 793)							
PP	0.034	−0.040	0.077	0.017	0.140[a]	52.10	53.09
CAT	0.037	0.002	0.042	−0.004	0.136[a]	0.10	0.14
EI (N = 518)							
PP	0.094	0.079	0.105	−0.023	0.189[a]	55.20	56.52
CAT	0.129[a]	0.122[a]	0.087	0.004	0.235[a]	0.28	0.44
SI (N = 735)							
PP (AS)[b]	0.068	0.020	0.038	0.031	0.022	56.04	55.55
CAT	0.075	0.028	0.059	−0.001	−0.023	0.37	0.30

a. $p < .01$.
b. PP AS test scores used as reference test for CAT AI and SI scores.

Equating

The sample sizes available for equating CAT to PP for each subtest within a subpopulation are shown in table 3. Note that some of the samples are quite small (less than 200 cases). Results from equating these small samples should be viewed with caution.

Subtest Level

The results of equating CAT to PP at the subtest level are presented graphically. Each graph contrasts a single subpopulation, for example, males versus females. (Corresponding equating tables are shown in appendix B.) Differences in the equating curves tend to appear at the low end of the score continuum. These differences, however, are associated with score intervals typically having fewer than 10 observations. Subjective comparisons of the curves are made.

Experience

Figure 3 contrasts the subtest level equatings for examinees with and without computer experience. Only one subtest, AR, shows that computer experience had any effect. Examinees with no experience and with PP scores below 50 tend to score about 0.2 theta-scale units lower than those with computer experience.

Gender

Contrasts for males and females are shown in figure 4. Little evidence of a gender effect is evident from these data. Note, however, that most of the female samples (6 out of 11) are small.

Race

Figure 5 contrasts equatings of Caucasians with minorities (non-Caucasians). Four of the subtests show a consistent racial bias. Minorities tend to have higher CAT scores, for a given PP score, than Caucasians on the AI and MK subtests. Minorities, however, tend to score lower on the CAT NO subtest, for a given PP NO score, than do Caucasians.

TABLE 3

SAMPLE SIZES FOR EQUATING

| | Subpopulation | | | | | | | |
| | Education | | Computer experience | | Gender | | Race | |
Subtest	Graduate	Nongraduate	Yes	No	Male	Female	Caucasian	Minority
GS	2,021	298	333	190[a]	2,201	118[a]	1,948	371
AR	3,348	333	404	252	3,638	43[a]	3,100	581
WK	3,562	479	851	526	3,485	556	2,848	1,193
PC	3,562	479	851	526	3,485	556	2,848	1,193
NO	2,356	320	653	372	2,206	470	1,760	916
CS	1,816	209	449	231	1,676	349	1,305	720
AI	2,556	391	436	299	2,801	146[a]	2,342	605
MK	1,762	287	306	164[a]	1,932	117[a]	1,717	332
MC	2,655	478	470	230	2,897	236	2,536	597
EI	2,504	324	323	195[a]	2,757	71[a]	2,411	417
SI	2,542	387	436	299	2,783	146[a]	2,325	604
Composite								
EL							1,229	163[a]
CL					1,300	349	999	650

a. Less than 200 cases.

-11-
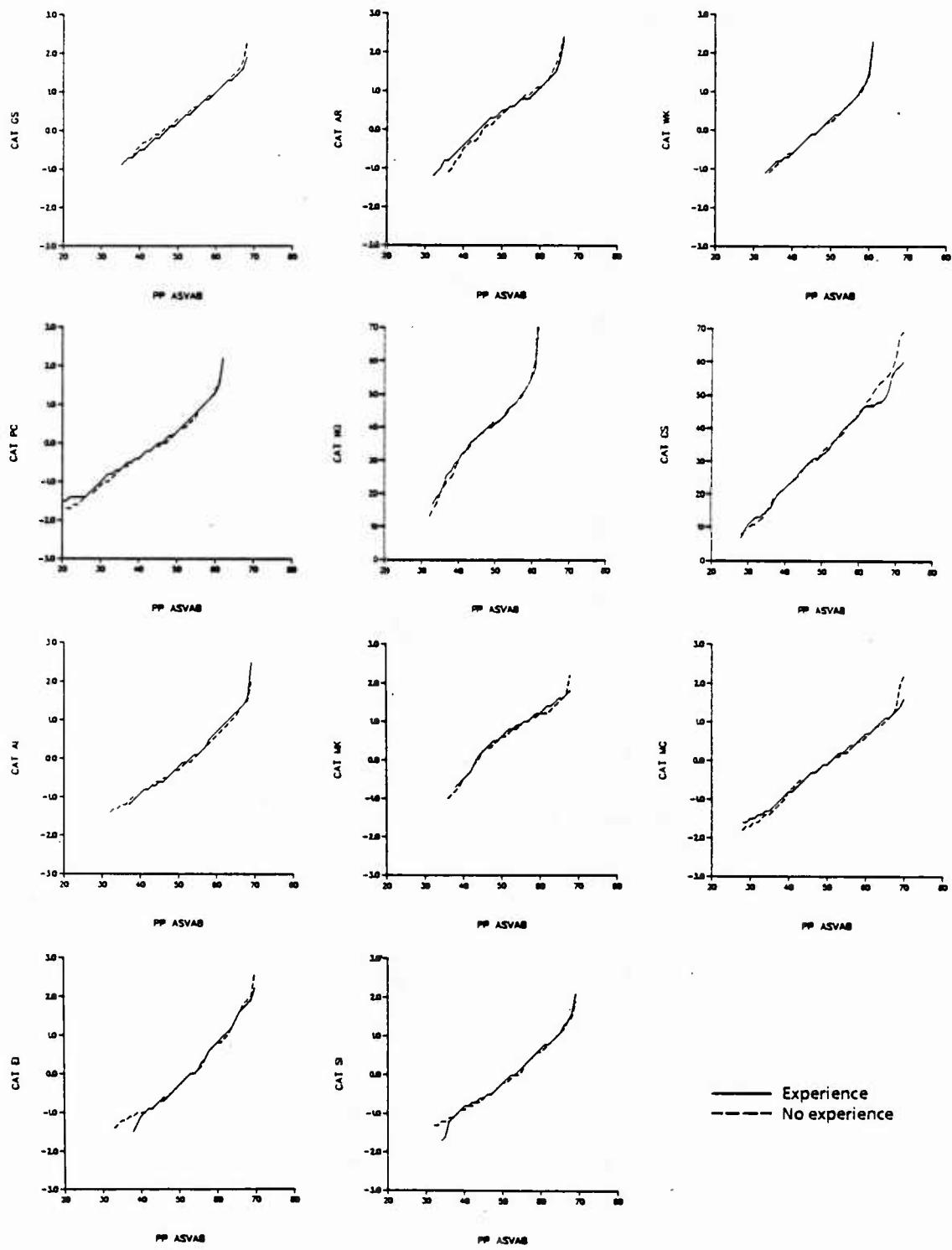
NOTE: Sample sizes were less than 200 for those without computer experience taking the GS, MK, and EI subtests.

FIG. 3: EQUIPERCENTILE EQUATING BY SUBPOPULATIONS
(COMPUTER EXPERIENCE)
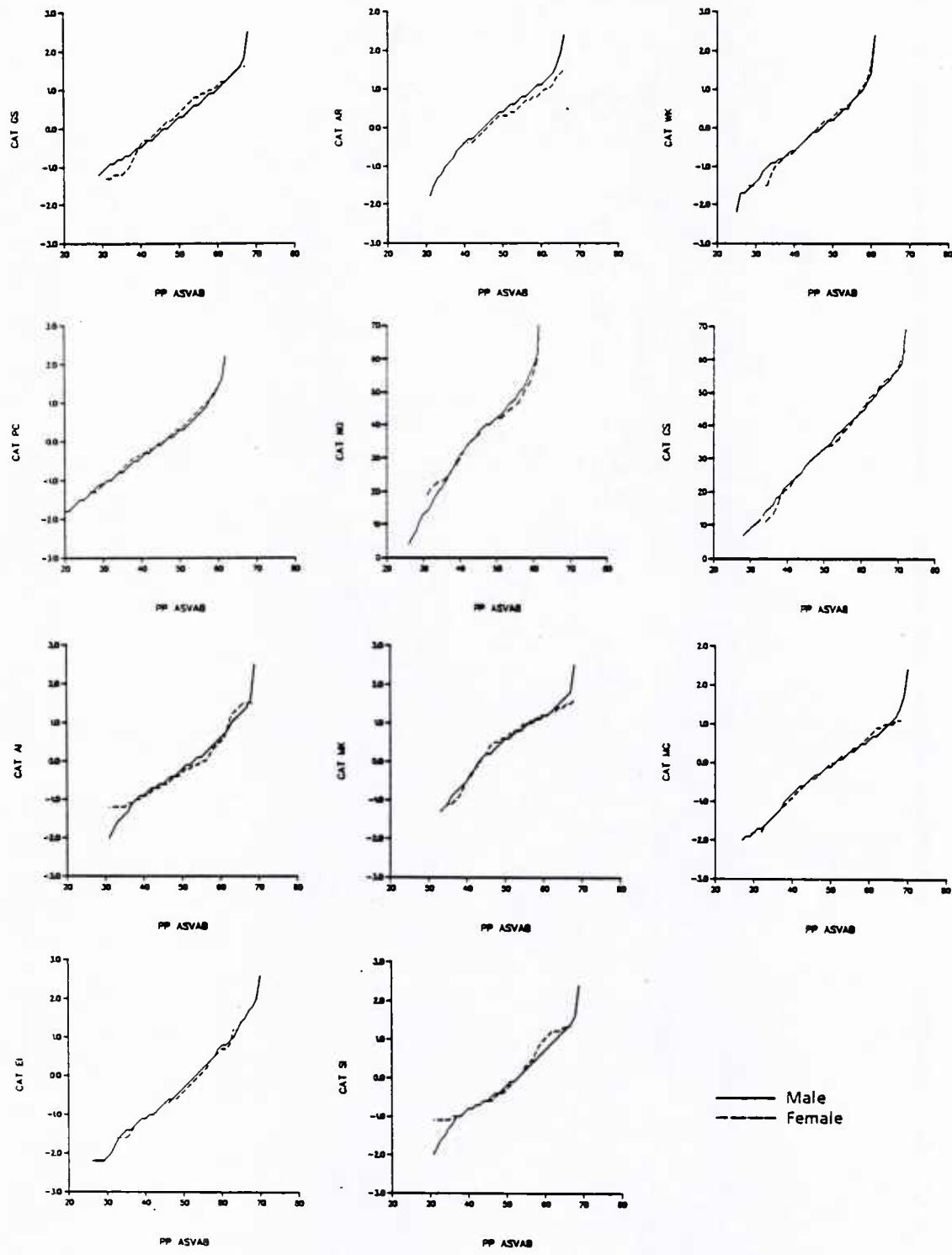
NOTE: Sample sizes were less than 200 for females taking the GS, AR, AI, MK, EI, and SI subtests.

FIG. 4: EQUIPERCENTILE EQUATING BY SUBPOPULATIONS
(GENDER)
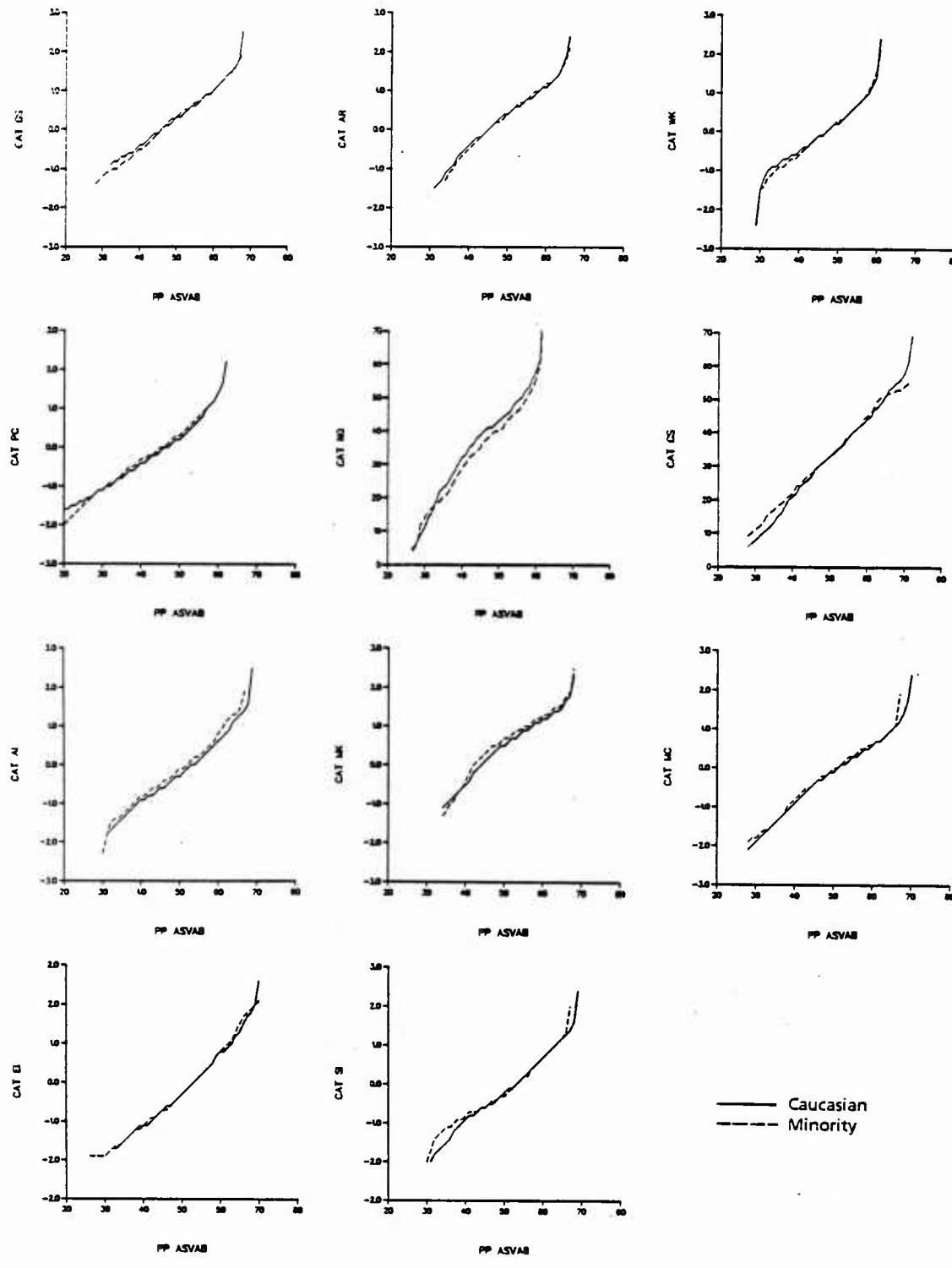
FIG. 5: EQUIPERCENTILE EQUATING BY SUBPOPULATIONS
(RACE)
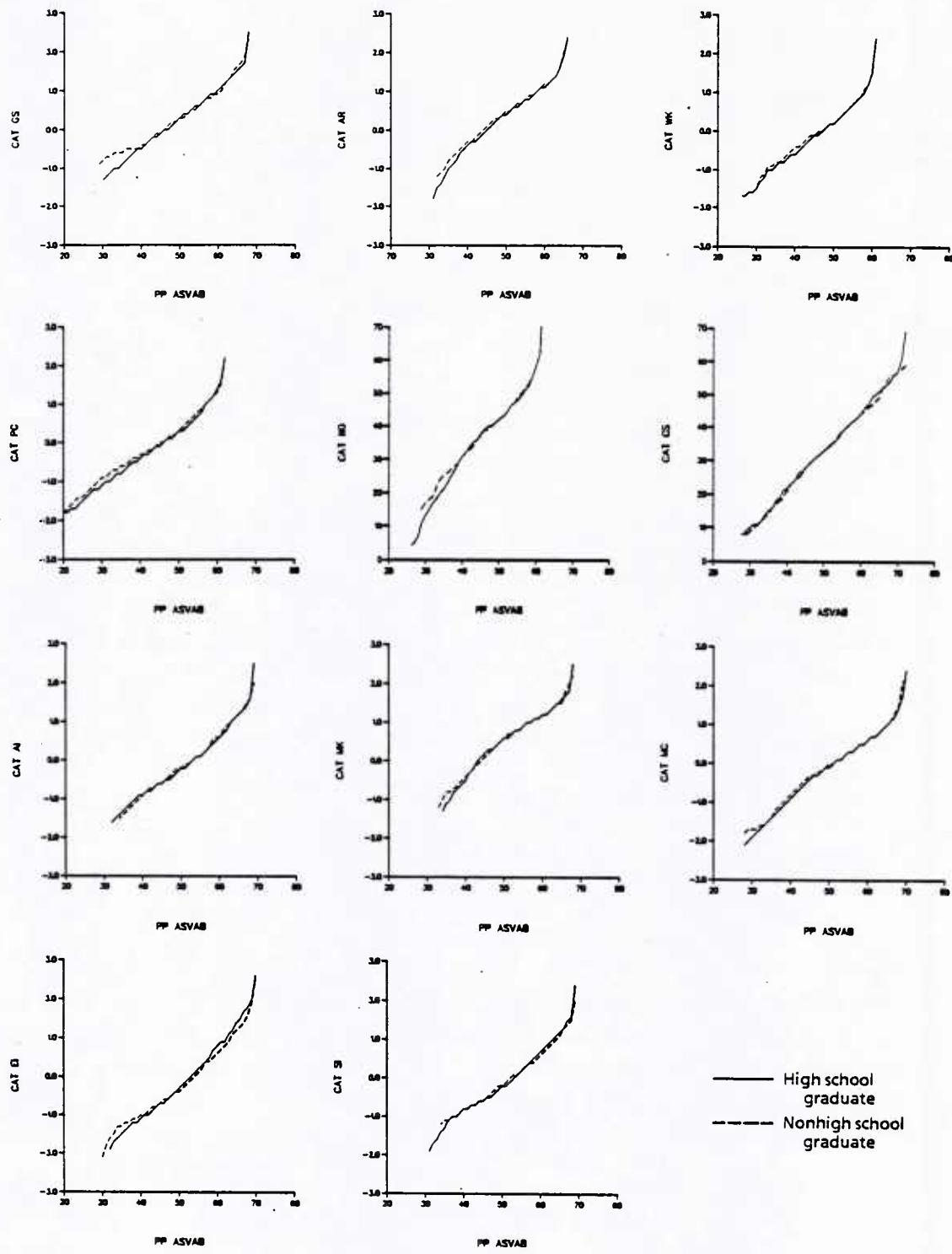
FIG. 6: EQUIPERCENTILE EQUATING BY SUBPOPULATIONS
(EDUCATION)

-15-

Education

Figure 6 contrasts high school graduates with nongraduates. Small differences are seen for the AR and PC subsets. For these subtests, nongraduates tend to score somewhat higher on CAT (0.1 to 0.2 scale points).

Aptitude Composites

Small samples permitted the construction of only two aptitude composites, Clerical (CL) and Electrical (EL). The equating of the CAT and PP composites are discussed below.

CL

The equating of the CAT to the PP composite for males and females is shown in the upper panel of figure 7. The lower panel of the figure shows the proportion of each subpopulation whose CAT scores equated to a given PP composite score. Differences in the male and female "curves" represents the selection bias that might occur using CAT scores, at any given PP score. Because the equating data were based on recruits selected on the basis of their PP scores, scores below the cutoff point were not observed. Only small differences in the region above a composite score of 120 are observed. These are of no practical significance.

Figure 8 shows the equating of CL for Caucasians and minorities. No large or consistent differences are observed.

EL

The data shown in figure 9 compare the equating of the EL composite for Caucasians and minorities, based on a small sample of minorities (163). The results suggest that minorities would benefit from being tested on CAT ASVAB for selection by EL. For example, at a cutting score of 90, about 8 percent more minorities would be selected with a CAT than with a PP test.

SUMMARY AND CONCLUSIONS

This analysis compared the equating of CAT to PP ASVAB subtests and aptitude composites in various subpopulations. Equating was generally

EQUITY COMPARISON
(CL COMPOSITE)

KS Two Sample (Chi Square) Statistic = 3.983
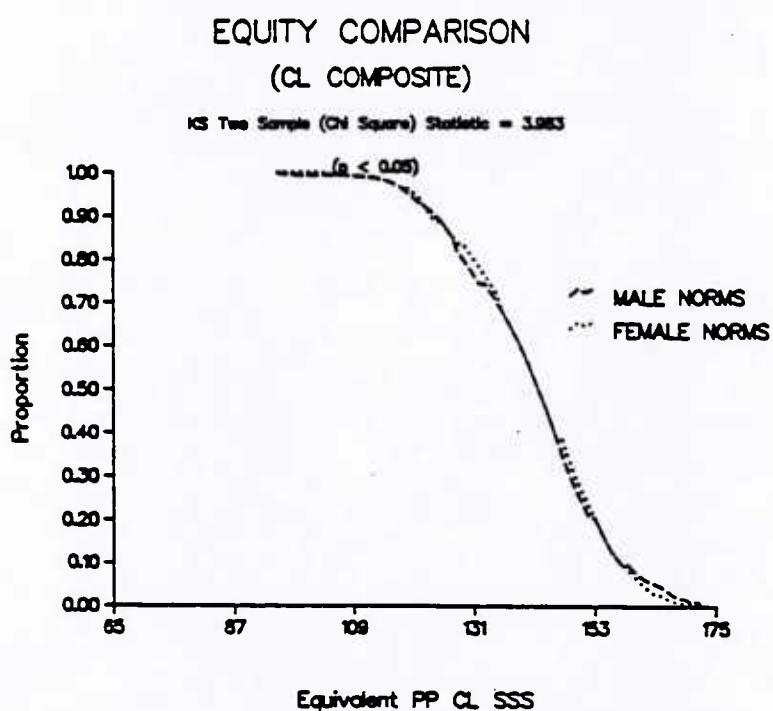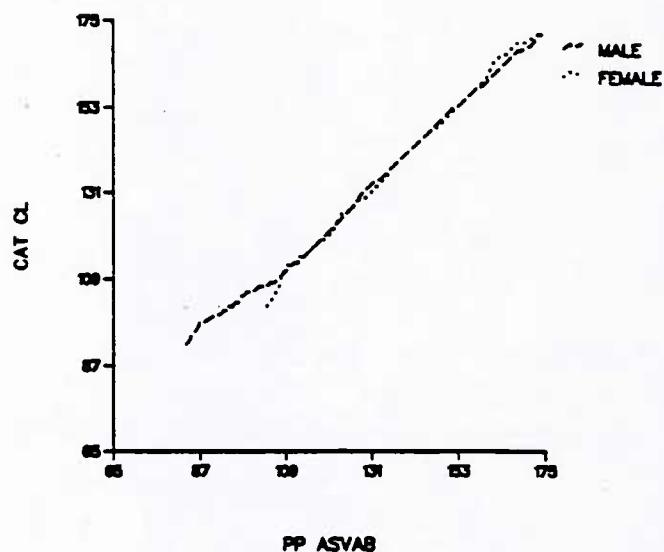
FIG. 7: CL COMPOSITE BY GENDER

-17-
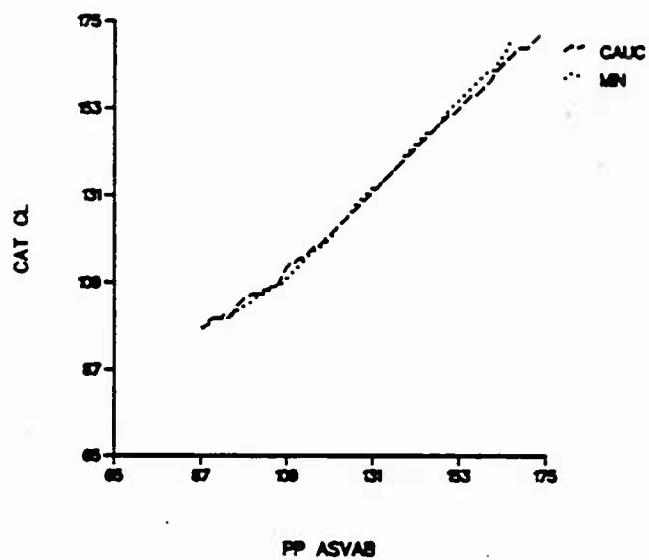
EQUITY COMPARISON
(CL COMPOSITE)

KS Two Sample (Chi Square) Statistic = 2.282

FIG. 8: CL COMPOSITE BY RACE

EQUITY COMPARISON
(EL COMPOSITE)

KS Two Sample (Chi Square) Statistic = 8.237

($p < 0.01$)
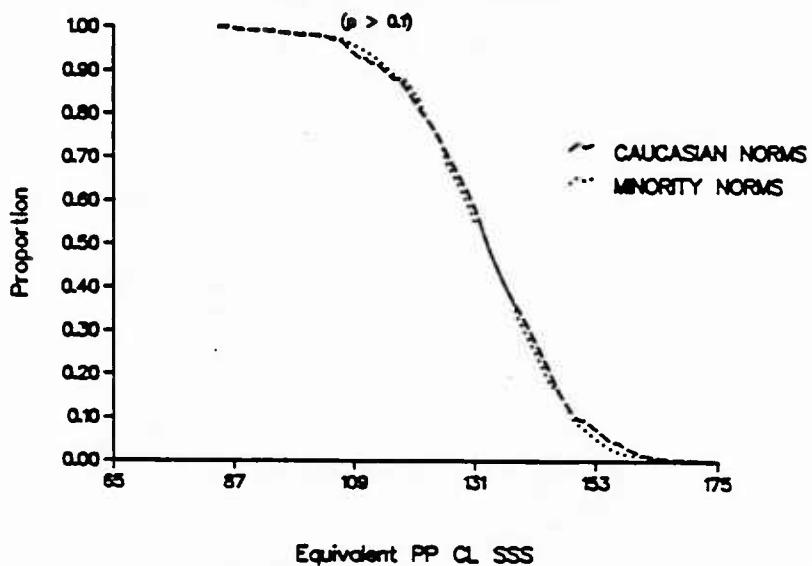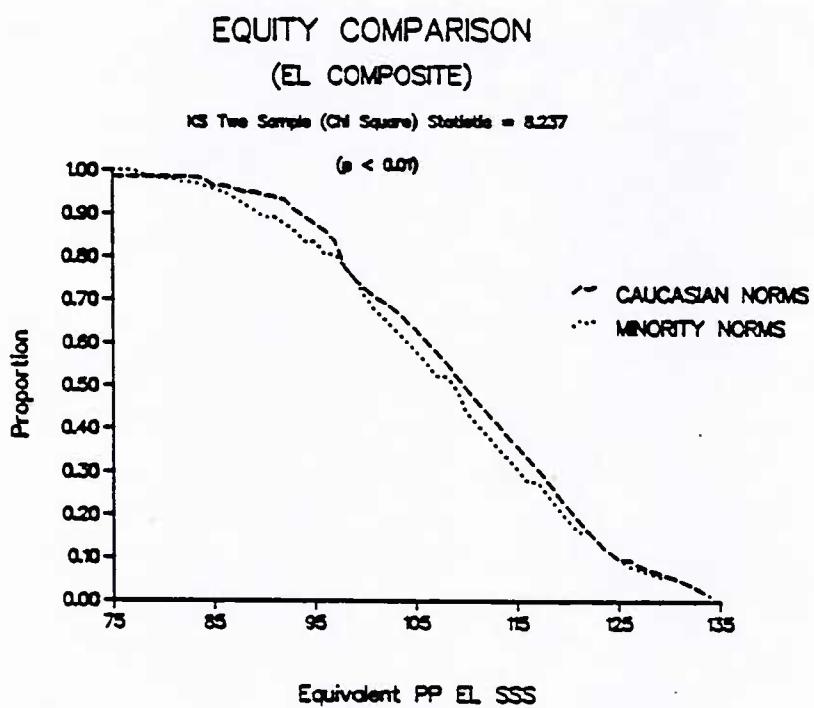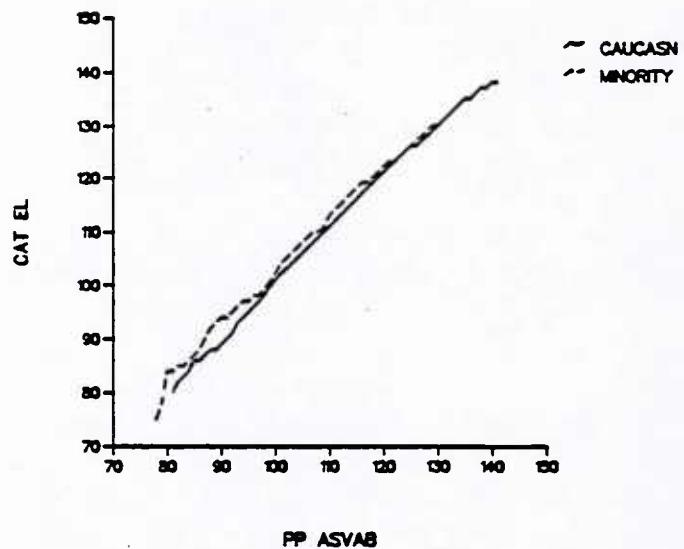
NOTE: Sample size was less than 200 for minorities.

FIG. 9: EL COMPOSITE BY RACE

-19-

independent of population group. Subjectively meaningful differences are noted, however, with respect to race for the NO, AI, and MK subsets. These differences, on the order of 2 to 3 ASVAB standard score points, are in such a direction as to favor minorities on the AI and MK subsets and to the disadvantage of minorities on the NO subset. Since NO is part of the AFQT, minorities could also be disadvantaged by 1 to 2 AFQT percentile points.

Two composites were also studied. No meaningful subpopulation differences were observed for CL. Small differences were noted for EL that would tend to favor minorities.

These results imply that subpopulation differences are not likely to be a major concern in the forthcoming ACAP testing program where CAT and PP scores will be equated. This suggests that the ACAP equating sample need not be precisely stratified along the dimensions represented by the subpopulation groups used here. The results also suggest that special training for examinees lacking experience with computers will not be necessary.

REFERENCES

[1] CNA, Report 113, *Equivalence of Scores From Computerized Adaptive and Paper-and-Pencil ASVAB Tests*, by Peter H. Stoloff, Nov 1985

[2] Rehab Group, Inc., *Predictive Validity Evaluation of Computerized Adaptive Testing: Results of the Navy Research*, by Susan B. Hardwicke and Kenneth D. White, Dec 1983

[3] Wingersky, M. S., "LOGIST: A Program for Computing Maximum Likelihood Procedures for Logistic Test Models" in *Applications of Item Response Theory*, R. K. Hambleton, ed., Vancouver: Educational Research Institute of British Columbia, 1983

[4] *SPSSx, User's Guide*, N.Y.: McGraw-Hill, 1983

APPENDIX A
CAT QUESTIONNAIRE

APPENDIX A

CAT QUESTIONNAIRE

The items contained in the questionnaire given to CAT examinees, along with mneumonics used as labels in table 1 of the main text, and scale values applied for quantifying responses are contained in this appendix.

QUESTIONNAIRE

BEFORE YOU LEAVE...

The computerized test you have just taken is an experimental test which will be administered to several thousand recruits. We are interested in examinees' reactions to the test, and their opinions of computerized testing. Your answers to this questionnaire will provide a valuable contribution in the evaluation of this testing process.

Some of the questions below will ask you for information. Others will ask you to state whether you agree with a statement or how often things happen. Please read each question carefully and follow the instructions for each set of questions.

CIRCLE THE APPROPRIATE ANSWERS FOR THE QUESTIONS BELOW.

Mneumonic	Scale value	Item
USEDC		1. I have used a computer . . .
	1	A. Never before
	2	B. Once or twice
	3	C. Occasionally
	4	D. Frequently
USEDT		2. I have used a typewriter . . .
	1	A. Never before
	2	B. Once or twice
	3	C. Occasionally
	4	D. Frequently
PASSIST		3. If you needed assistance, was the proctor helpful?
	1	A. Yes
	3	B. No
	2	C. I did not need assistance

SCNRATE | 4. The test questions appeared on the screen . . .

1	A. Too fast
3	B. Too slow
2	C. At about the right speed

CVSPPD | 5. Overall, the computerized test was . . .

1	A. More difficult than the paper and pencil tests
3	B. Easier than the paper and pencil test
2	C. About as difficult as the paper and pencil test

CVSPPS | 6. The computerized test was . . .

1	A. Faster than the paper and pencil test
3	B. Slower than the paper and pencil test
2	C. About the same as the paper and pencil test

READQ | 7. I could read the test questions on the screen . . .

1	A. With great difficulty
2	B. With some difficulty
3	C. Easily
4	D. Very easily

8. *If you had difficulty* in reading the test questions or viewing the screen, please circle all items below which relate to those difficulties. Otherwise, leave blank.

GLARE	0,1	A. Glare on the screen
SPACE	0,1	B. Not enough space between lines
TYPE	0,1	C. Difficulty in reading the type of lettering
LAYOUT	0,1	D. Layout of the questions on the screen
CONTRAST	0,1	E. Not enough contrast between screen and letters
SIZE	0,1	F. Size of letters was too small

CONFUS | 9. The test was confusing . . .

0	A.	Only during the instructions
0	B.	Only when answering questions
0	C.	During both instructions and answering questions
1	D.	Not at all

10. Please list any area of the test which was confusing.

_____ not used _____

_____

_____

TIRED1

11. My eyes felt tired . . .
1   A.   Frequently
2   B.   Occasionally
3   C.   Once or twice
4   D.   Not at all

FOR THE QUESTIONS BELOW, CIRCLE THE ANSWER THAT COMES CLOSEST TO MATCHING YOUR JUDGMENT OR OPINION.

INSCLR

12. How clear do you feel the computerized instructions were?
1   A.   Very clear — I had no trouble at all with them
2   B.   Clear enough, in general — but could be improved
3   C.   Unclear in places or in part
4   D.   Very unclear and confusing

RUSHED

13. Did you have enough time to give your answers?
1   A.   I didn't feel rushed or pressured at all
2   B.   I felt a little rushed and could have used more time
3   C.   I felt rushed and pressed for time

EASCOR

14. Could you make corrections easily enough?
1   A.   The correction method is simple — I had no problems
2   B.   I had some problems — in some cases I wanted to change my answer after it was too late
3   C.   I had serious problems — in many cases I wanted to change my answer after it was too late

DIFFLEV   15. What is your opinion of the difficulty level of the
                           questions?
1   A. They were too difficult
2   B. They were about right
3   C. They were too easy

THE QUESTIONS BELOW ASK WHETHER YOU AGREE, DISAGREE, OR ARE UNDECIDED ABOUT CERTAIN STATEMENTS. CIRCLE THE RESPONSE WHICH MOST CLOSELY REPRESENTS YOUR OPINION.

USDP   16. I understood the *proctor's* instructions and
                           introduction to the test.
1   A. Agree
3   B. Disagree
2   C. Undecided

NEEDPI   17. I did not need the *proctor's* instructions in order to
                           take the test.
1   A. Agree
3   B. Disagree
2   C. Undecided

NEEDCI   18. I did not need the *computerized* instructions in
                           order to take the test.
1   A. Agree
3   B. Disagree
2   C. Undecided

LOCKEY   19. I had difficulty in *locating* the proper keys on the
                           keyboard.
1   A. Agree
3   B. Disagree
2   C. Undecided

PRESKEY   20. I had difficulty in *pressing* the right keys.
1   A. Agree
3   B. Disagree
2   C. Undecided

UNEASY

21. I felt uneasy about taking the test on a computer.
1   A. Agree
3   B. Disagree
2   C. Undecided

NOISE

22. The noise from the computer bothered me while I was taking the test.
1   A. Agree
3   B. Disagree
2   C. Undecided

UNSTDST

23. On the speeded tests, it was easy to understand how to answer the questions.
1   A. Agree
3   B. Disagree
2   C. Undecided

IMPERS

24. Computerized testing is more impersonal than paper and pencil testing.
1   A. Agree
3   B. Disagree
2   C. Undecided

ENJOY

25. I enjoyed taking the test on a computer.
1   A. Agree
3   B. Disagree
2   C. Undecided

NOTCH

26. I was bothered by not being able to change my answers at the end of each section of the test.
1   A. Agree
3   B. Disagree
2   C. Undecided

TIRED2

27. My eyes were tired by the end of the test.
1   A. Agree
3   B. Disagree
2   C. Undecided

**FOR THE QUESTION BELOW, PLEASE FILL IN THE
INFORMATION REQUESTED.**

NOTIMES

1. Approximately how many times during the test did you want to skip questions and come back to them?

_____ times

APPENDIX B

EQUATING TABLES

APPENDIX B

EQUATING TABLES

CAT scores, equivalent to PP ASVAB standard subtest scores (SS), in the 1980 metric are shown for the CAT subtests for various subpopulations. The CAT scores are linearly transformed, using an additive constant of 50, and a multiplier of 10. This results in a range of scale values of 20-80, which corresponds to a range of ±3 in the original theta metric.

TABLE B-1

EQUIVALENT CAT SCORES: TOTAL SAMPLE

PP score						CAT score					
	–GS–	–AR–	–WK–	–PC–	–NO–	–CS–	–AS–	–MK–	–MC–	–EI–	–SI–
18				31							
19				31							
20				32							
21				32							
22				33							
23				34	4						
24				35	4						
25			28	35	4						
26			32	36	4					28	
27			33	37	6				29	28	
28			33	38	8	7			30	28	
29	37		34	39	12	9			31	28	
30	38		35	39	14	10	29		32	29	
31	39	32	37	40	16	10	32		32	30	29
32	40	35	38	40	17	11	34		33	32	32
33	41	37	40	41	19	12	35	37	34	33	34
34	41	38	40	42	20	13	36	38	35	35	35
35	42	40	41	42	22	15	37	39	36	35	36
36	42	41	42	43	23	16	38	41	37	36	38
37	43	42	42	44	25	18	39	42	38	37	39
38	44	44	43	45	27	19	40	43	39	38	40
39	45	45	44	45	29	21	41	44	41	39	40
40	45	46	44	46	31	22	41	45	42	39	41
41	46	47	45	47	32	23	42	47	43	40	42
42	47	47	46	47	34	24	42	48	43	40	42
43	48	48	47	48	35	25	43	50	44	41	43
44	48	49	48	49	36	26	44	51	45	42	43
45	49	50	49	49	38	28	44	52	46	43	44
46	50	51	49	50	39	29	45	53	47	44	44
47	51	52	50	51	40	30	46	53	47	44	45
48	51	53	51	51	40	31	46	54	48	45	45
49	52	54	52	52	41	32	47	55	49	46	46
50	53	54	52	53	42	33	48	56	49	47	47
51	54	55	53	53	43	34	49	56	50	48	48
52	54	56	54	54	44	35	49	57	51	49	48
53	55	56	55	55	46	36	50	58	51	50	49
54	56	57	56	56	47	38	51	58	52	51	50
55	56	58	57	57	48	39	51	59	53	52	51
56	57	58	58	58	49	40	52	60	53	53	52
57	58	59	59	60	51	41	53	60	54	54	53
58	59	60	60	61	53	42	54	61	55	55	54
59	59	61	62	62	55	43	55	61	55	57	55
60	60	61	65	64	58	44	56	62	56	58	56
61	61	62	74	66	62	46	57	62	57	58	57
62	62	63		72	91	47	58	63	57	59	58
63	63	64				48	60	64	58	60	59
64	64	66				50	61	65	59	62	60
65	65	68				51	62	65	60	64	61
66	66	74				52	63	67	61	65	62
67	68					53	64	68	62	67	63
68	75					55	66	75	64	68	64
69						56	75		67	70	66
70						57			74	76	74
71						60					
72						69					

TABLE B-2

EQUIVALENT CAT SCORES BY COMPUTER EXPERIENCE GROUP

CAT score

PP score	GS Y	GS N	AR Y	AR N	WK Y	WK N	PC Y	PC N	NO Y	NO N	CS Y	CS N	AS Y	AS N	MK Y	MK N	MC Y	MC N	EI Y	EI N	SI Y	SI N
19							35															
20							35															
21							35	33														
22							36	33														
23							36	34														
24							36	34														
25							36	35														
26							36	36														
27							37	37														
28							38	37			7	8					34	32				
29							39	38			9	9					34	33				
30							40	39			11	10					35	33				
31							41	40			12	11					35	34				
32			38				42	40		13	13	11	36				36	34				37
33			39		39		42	41	17	15	13	12	37				36	35		36		37
34			40		40	39	43	42	19	17	14	13	37				37	36		37	33	38
35	41		42		41	40	43	43	20	20	15	15	38				37	36		38	34	38
36	42		42	39	42	41	44	44	23	22	16	17	38			40	38	37		38	38	39
37	43		43	40	42	42	45	44	26	24	18	19	38	39		41	39	38		39	39	39
38	43	43	44	42	43	43	45	45	27	25	20	20	39	40	43	42	40	39	35	39	40	40
39	44	45	45	43	43	44	46	46	29	27	21	21	40	40	44	43	41	40	37	40	41	41
40	45	46	46	45	44	44	46	46	30	30	22	22	41	41	45	45	42	42	39	40	42	41
41	45	47	47	46	45	45	47	47	32	32	23	23	42	42	46	46	42	43	40	40	42	42
42	46	47	48	47	46	46	48	48	33	33	24	24	42	42	47	47	43	44	41	41	43	42
43	47	48	49	47	47	47	48	48	35	34	25	25	43	43	49	49	44	45	41	41	43	43
44	48	49	50	48	48	48	49	49	36	36	27	26	43	44	51	50	45	45	42	42	44	43
45	48	49	51	50	49	49	50	49	37	37	28	28	44	44	52	52	46	46	43	43	44	44
46	49	50	52	51	49	49	50	50	38	38	29	29	44	45	53	53	47	47	43	44	45	45
47	50	51	53	51	50	50	51	50	39	39	30	30	45	45	54	53	47	47	44	44	45	45
48	51	51	53	52	51	51	52	51	40	40	31	30	46	46	55	54	48	48	45	45	46	46
49	51	52	54	53	52	52	52	52	40	41	31	31	47	47	55	55	49	49	46	46	47	47
50	52	53	55	54	53	52	53	53	41	42	32	33	48	47	56	56	49	49	47	47	48	48
51	53	53	55	55	54	53	54	54	42	42	33	34	49	48	57	56	50	50	48	48	49	48
52	54	54	56	56	54	54	55	54	43	43	34	35	49	49	58	57	51	51	49	49	50	49
53	54	55	56	56	55	55	56	55	44	45	36	36	50	49	58	58	52	51	50	50	50	50
54	55	56	57	57	56	56	57	56	46	46	37	37	51	50	59	58	52	52	50	50	51	50
55	56	56	58	58	57	57	58	57	47	47	39	38	51	51	59	59	53	52	51	51	52	51
56	57	57	58	59	58	58	59	59	48	48	40	39	52	52	60	60	54	53	53	52	53	53
57	58	58	58	59	59	59	60	60	50	49	41	41	53	53	60	60	54	54	54	54	54	54
58	58	59	59	60	61	60	61	61	51	51	42	42	55	54	61	61	55	55	56	56	55	55
59	59	59	60	61	62	62	62	62	53	53	43	43	56	55	62	61	56	55	57	57	56	56
60	60	60	61	61	65	64	63	64	55	56	44	45	57	56	62	62	57	56	58	58	57	56
61	61	61	62	62	73	73	65	66	58	61	46	46	58	57	63	62	57	57	59	58	58	57
62	62	62	63	63			72	72	73	91	47	48	59	58	64	62	58	58	60	59	58	58
63	63	63	64	65							47	49	60	59	64	63	59	59	61	60	59	59
64	63	64	65	67							47	51	61	60	65	64	60	59	62	62	60	60
65	64	65	68	70							48	53	62	61	66	65	61	60	64	64	61	61
66	65	66	73	74							48	54	63	63	66	66	61	61	66	66	63	62
67	66	68									49	55	64	64	67	67	62	62	67	68	64	64
68	69	73									51	56	66	65	68	72	63	64	68	69	66	65
69											56	58	75	70			64	70	69	70	71	69
70											58	61					66	72	69	72	72	76
71											59	68							72	76		
72											60	69										

NOTE: Y = computer experience, N = no computer experience.

TABLE B-3

EQUIVALENT CAT SCORES BY EDUCATIONAL GROUP

CAT score

PP score	-GS-		-AR-		-WK-		-PC-		-NO-		-CS-		-AS-		-MK-		-MC-		-EI-		-SI-	
	G	NG	G	NG	G	NG	G	NG	G	NG	G	NG	G	NG	G	NG	G	NG	G	NG	G	NG
19							31	32														
20							32	32														
21							32	33														
22							33	34														
23							33	35	4													
24							34	36	4													
25					28		35	36	4													
26					33		36	37	4											28			
27					33		37	38	5											29			
28					34		38	39	7		8						29	32		29			
29		41			34	34	38	40	11	15	9	8					30	33		29			
30	37	42			35	35	39	41	13	17	10	9					31	33		29			
31	38	43	32		37	38	40	41	15	18	11	10	30	35			32	33	32		31	38
32	39	43	35	38	38	39	40	42	17	19	11	11	34	35			33	34	31	34	33	38
33	40	44	36	39	40	41	41	43	18	22	12	12	35	35		38	34	34	33	35	34	38
34	40	44	38	40	40	41	42	43	20	24	14	13	36	35	37	40	35	35	34	37	36	38
35	41	44	40	42	41	42	42	44	21	25	15	14	37	36	39	42	36	36	35	37	37	39
36	42	45	41	43	42	42	43	44	23	26	16	16	38	37	40	42	37	38	36	38	39	39
37	43	45	42	44	42	43	44	45	25	27	18	17	39	38	42	43	38	39	37	38	40	40
38	44	45	44	45	43	44	45	46	27	28	19	18	40	39	43	44	39	40	38	39	40	40
39	45	45	45	46	44	45	45	46	29	29	21	19	41	40	44	45	40	41	38	39	41	41
40	45	46	46	47	44	46	46	47	31	31	22	21	41	41	45	46	41	42	39	40	42	42
41	46	46	47	47	45	46	47	47	32	32	23	23	42	42	47	47	42	43	40	40	42	42
42	47	47	47	48	46	47	47	48	34	33	24	24	42	43	48	48	43	44	40	41	43	43
43	48	48	48	49	47	48	48	48	35	34	25	26	43	43	50	49	44	45	41	42	43	43
44	48	49	49	50	48	49	49	49	36	36	26	27	44	44	51	50	45	46	42	42	44	44
45	49	49	50	51	49	49	49	50	38	37	28	28	44	44	52	51	46	47	43	43	44	44
46	50	50	51	52	49	50	50	50	39	39	29	29	45	45	53	52	47	47	43	44	45	45
47	50	51	52	53	50	50	51	51	40	39	30	30	45	46	53	53	47	48	44	44	45	46
48	51	52	53	53	51	51	51	52	40	40	31	31	46	47	54	54	48	48	45	45	46	47
49	52	52	54	54	52	52	52	52	41	41	32	32	47	48	55	55	49	49	46	46	47	48
50	53	53	54	55	52	52	53	53	42	42	33	33	48	48	56	56	49	50	47	46	48	48
51	54	53	55	55	53	53	53	54	43	43	34	34	48	49	56	57	50	50	48	47	48	49
52	54	54	56	56	54	54	54	55	44	44	35	35	49	49	57	57	51	51	49	48	49	50
53	55	55	56	57	55	55	55	56	46	46	36	36	50	50	58	58	51	51	50	49	50	51
54	56	55	57	57	56	56	56	57	47	47	38	37	51	51	58	58	52	52	51	50	51	51
55	56	56	58	58	57	57	57	58	48	49	39	39	51	51	59	59	53	53	52	51	52	52
56	57	57	58	59	58	58	58	59	49	50	40	40	52	52	60	60	53	53	53	52	53	53
57	58	58	59	59	59	59	60	60	51	52	41	41	53	53	60	60	54	54	54	54	54	54
58	59	58	60	60	60	61	61	61	52	53	42	42	54	55	61	61	55	55	55	54	55	54
59	59	59	61	61	62	62	62	62	55	55	43	43	55	56	61	61	55	55	57	55	56	55
60	60	59	61	62	65	65	64	63	58	58	44	44	56	56	62	62	56	56	58	56	57	56
61	61	60	62	62	74	74	66	65	62	62	46	45	57	58	62	62	57	57	59	57	58	57
62	62	62	63	63			72	72	91	81	47	46	58	59	63	63	57	57	59	58	59	58
63	63	63	64	64							49	47	60	60	64	64	58	58	61	59	60	59
64	64	65	66	66							50	48	61	61	65	65	59	59	62	61	61	60
65	65	66	69	70							51	49	62	62	65	66	60	60	64	62	62	61
66	66	67	74	73							52	52	63	63	67	68	61	61	65	63	63	63
67	67	69									53	54	64	65	68	70	62	63	67	64	65	64
68	75	73									54	56	66	66	75	72	64	65	68	66	66	65
69											56	56	75	70			67	71	70	69	74	70
70											57	57					74	72	76	75		
71											61	58										
72											69	59										

NOTE: G = high school graduate, NG = nongraduate.

B-4

TABLE B-4

EQUIVALENT CAT SCORES BY RACIAL GROUP

CAT score

PP score	GS C	GS M	AR C	AR M	WK C	WK M	PC C	PC M	NO C	NO M	CS C	CS M	AS C	AS M	MK C	MK M	MC C	MC M	EI C	EI M	SI C	SI M
18							33															
19							33															
20							34	30														
21							34	31														
22							35	32														
23							35	33	4													
24							36	34	4													
25						32	36	35	4													
26						34	37	36	4										31			
27						34	37	37	5	4									31			
28		36				34	38	38	7	7	6	9					29	31	31			
29		37			26	34	39	39	9	12	7	10					30	32	31			
30		38			35	35	39	39	11	14	8	11		27			31	32	31			30
31		39	35		38	36	40	40	14	16	9	12	32	31			32	33	32		30	33
32	41	39	36		40	38	40	41	16	17	10	13	33	35			33	34	33		32	36
33	42	40	37		41	39	41	41	19	18	11	15	34	36			34	34	33	34	33	37
34	42	40	39	37	41	40	42	42	22	19	12	16	35	36	39	37	35	35	34	34	34	38
35	43	41	40	39	42	41	42	43	23	20	13	17	36	37	40	38	36	36	35	35	35	39
36	43	42	41	40	43	41	43	44	24	21	15	18	37	38	41	40	37	37	36	36	36	39
37	44	42	43	42	43	42	44	45	26	23	16	19	38	39	42	41	38	38	37	37	38	40
38	44	43	44	43	44	43	44	45	28	25	18	20	39	40	43	43	39	40	38	38	39	41
39	45	44	45	44	44	43	45	46	30	27	20	21	40	41	44	44	40	41	38	39	40	41
40	46	45	46	45	45	44	46	47	32	29	21	22	41	42	45	46	41	42	39	39	41	42
41	46	45	47	46	46	45	46	47	33	30	22	24	41	42	46	48	42	43	39	40	42	43
42	47	46	48	47	46	46	47	48	35	32	24	25	42	43	48	50	43	44	40	41	42	43
43	48	47	48	48	47	47	48	48	36	33	25	26	42	44	49	51	44	45	41	41	43	43
44	49	48	49	49	48	48	48	49	38	34	26	27	43	44	50	52	45	45	42	42	44	44
45	49	49	50	50	49	49	49	50	39	35	27	28	44	45	51	53	46	46	43	43	44	44
46	50	50	51	51	49	49	50	50	40	37	29	29	44	46	52	54	47	47	44	43	45	45
47	51	51	52	52	50	50	50	51	41	38	30	30	45	46	53	55	47	48	44	44	45	46
48	51	52	53	52	51	51	51	52	41	39	31	31	46	47	54	55	48	48	45	45	46	46
49	52	53	54	53	52	52	52	53	42	40	32	32	47	48	55	56	49	49	46	46	47	47
50	53	53	54	54	52	53	52	53	43	40	33	33	47	49	55	57	49	50	47	47	48	47
51	53	54	55	55	53	53	53	54	44	41	34	34	48	49	56	57	50	50	48	48	49	48
52	54	55	56	56	54	54	54	55	45	43	35	35	49	50	57	58	51	51	49	49	49	49
53	55	55	56	57	55	55	55	56	46	44	36	36	50	51	57	59	51	52	50	50	50	50
54	56	56	57	57	56	56	56	57	48	45	37	38	50	52	58	59	52	53	51	51	51	51
55	56	57	58	58	57	57	57	58	49	46	39	39	51	52	59	60	53	53	52	52	52	52
56	57	57	58	59	58	58	58	59	50	47	40	40	52	53	59	60	53	54	53	53	53	52
57	58	58	59	60	59	59	60	60	52	49	41	41	53	54	60	61	54	55	54	54	54	54
58	59	59	60	60	60	61	61	61	53	51	42	42	54	55	61	62	55	55	55	55	55	55
59	59	59	61	61	62	63	62	62	56	53	43	44	55	56	61	62	55	56	57	57	56	56
60	60	60	61	62	64	66	64	64	58	56	44	45	56	58	62	63	56	56	58	58	57	57
61	61	61	62	62	74	71	66	66	62	60	45	45	57	59	62	63	57	57	58	59	58	58
62	62	62	63	63			72	72	91	76	47	48	58	61	63	64	57	57	59	60	59	59
63	63	63	64	64							48	50	59	62	64	65	58	58	60	61	60	60
64	64	64	66	66							49	51	61	63	64	65	59	59	62	63	61	61
65	65	65	69	68							51	51	62	63	65	66	60	60	63	65	62	62
66	66	66	74	71							53	52	63	65	67	68	61	61	65	67	63	64
67	68	68									54	52	64	69	68	69	62	69	67	68	64	70
68	75	70									55	53	66		73	75	64		68	69	66	
69											56	53	75				67		70	70	74	
70											58	54					74		76	71		
71											61	55										
72											69	56										

NOTE: C = Caucasian, M = non-Caucasian.

EQUIVALENT CAT SCORES BY GENDER GROUP

CAT score

PP score	GS M	GS F	AR M	AR F	WK M	WK F	PC M	PC F	NO M	NO F	CS M	CS F	AS M	AS F	MK M	MK F	MC M	MC F	EI M	EI F	SI M	SI F
17							30															
18							31															
19							31															
20							32															
21							32															
22							33															
23							34		4													
24							35		4													
25					28		35		4													
26					33		36		4										28			
27					33		37	37	6								30		28			
28					34		38	37	8		7						31		28			
29	38				35		39	38	11		8						31		28			
30	39				36		39	39	13		9						32		29			
31	40	37	32		37		40	40	14	19	10		30				33		30		30	
32	41	37	35		39		40	40	16	21	11		32	38			33	32	32		32	39
33	41	38	37		40	35	41	41	18	22	12		34	38	37		34	34	34		34	39
34	42	38	38		41	38	42	42	20	23	14	11	35	38	38		35	35	35		35	39
35	42	38	40		41	40	42	43	21	23	15	12	36	38	39		36	36	36	34	37	39
36	43	39	41		42	41	43	44	23	24	16	13	37	39	41	39	37	37	36	35	38	40
37	43	40	42		42	42	44	45	25	25	18	15	39	39	42	40	38	38	37	37	40	40
38	44	42	44		43	43	45	46	27	27	19	18	40	40	43	41	40	39	38	38	40	40
39	45	44	45		44	43	45	46	29	28	21	20	41	40	44	43	41	40	39	39	41	41
40	45	46	46		44	44	46	47	31	30	22	21	41	41	45	45	42	41	39	39	42	42
41	46	47	47		45	45	47	47	32	32	23	22	42	41	47	46	43	42	40	40	42	42
42	47	47	47	46	46	46	47	48	34	34	24	24	43	42	48	48	44	43	40	40	43	43
43	47	48	48	47	47	47	48	48	35	35	25	25	43	43	50	49	44	44	41	41	43	43
44	48	49	49	48	48	48	49	49	36	36	26	26	44	43	51	51	45	45	42	42	44	44
45	49	50	50	49	49	49	49	50	38	37	28	28	44	44	52	52	46	46	43	43	44	44
46	50	51	51	50	49	50	50	50	39	39	29	29	45	44	52	54	47	46	44	43	45	44
47	50	52	52	51	50	51	51	51	40	40	30	30	46	45	53	55	47	47	44	44	46	45
48	51	52	53	52	51	52	51	52	40	40	31	31	46	46	54	55	48	48	45	44	46	46
49	52	53	54	53	52	52	52	53	41	41	32	32	47	46	55	56	49	49	46	45	47	46
50	53	54	54	53	52	53	53	53	42	42	33	33	48	47	56	56	49	50	47	46	48	47
51	53	55	55	53	53	54	53	54	43	42	34	34	49	48	56	57	50	50	48	47	49	48
52	54	56	56	54	54	55	54	54	44	43	35	34	49	48	57	58	51	51	49	48	49	49
53	55	57	56	54	55	55	55	56	46	44	37	35	50	49	58	58	51	52	50	49	50	50
54	56	58	57	55	55	56	56	57	47	45	38	36	51	49	58	59	52	52	51	50	51	51
55	56	58	58	56	57	57	57	58	48	46	39	38	51	50	59	60	53	53	52	51	52	53
56	57	59	58	57	58	58	58	59	50	47	40	39	52	50	60	60	53	54	53	52	53	54
57	58	59	59	57	59	60	59	60	51	49	41	40	53	51	60	61	54	54	54	54	54	55
58	59	60	60	58	60	61	61	61	53	51	42	42	54	53	61	61	55	55	55	55	55	57
59	59	60	61	58	62	63	62	63	56	53	43	43	55	54	61	62	55	56	57	56	56	59
60	60	61	61	59	64	67	64	64	58	56	44	45	56	55	62	62	56	57	57	57	57	60
61	61	62	62	60	74	74	66	66	62	60	45	46	57	56	62	62	57	58	58	57	58	61
62	62	62	63	60			72	72	82	91	47	48	58	59	63	63	57	59	59	58	59	62
63	63	63	64	61							48	49	60	62	64	63	58	59	60	62	60	62
64	64	64	66	63							49	50	61	63	65	64	59	60	62		61	62
65	65	65	69	64							51	52	62	64	66	64	60	60	64		62	63
66	66	66	74	65							52	53	63	65	67	65	61	60	65		63	63
67	68										53	54	64		68	65	62	61	67		64	
68	75										54	55	66		75	66	64	61	68		66	
69											56	56	75				67		70		74	
70											57	58					74		76			
71											59	61										
72											69	63										

NOTE: M = male, F = female.

B-6

EQUIVALENT PAPER-AND-PENCIL SCORES FOR CAT COMPOSITES
(Composite/Subpopulation)

CAT Composite score

PP score	CL Cauc	CL Min	CL Male	CL Fem	EL Cauc	EL Min
67						
68		91				
69		92	92			
70		93	92			
71		93	92			
72		93	92			
73		93	92			
74		93	92			
75		93	92			
76		93	92		80	
77		93	92		80	
78		93	92		80	75
79		93	92		80	78
80		93	92		80	84
81		93	92		80	84
82		93	92		82	85
83		93	92		83	85
84		93	93		84	86
85		94	95		86	87
86		96	96		86	88
87	98	97	98		87	90
88	99	98	98		88	92
89	99	99	99		88	93
90	100	99	99		89	94
91	100	100	100		90	94
92	100	100	100		91	95
93	100	101	101		93	96
94	100	101	101		94	97
95	101	101	102		95	97
96	103	102	103		96	98
97	104	102	103		97	98
98	105	103	105		99	99
99	106	103	106		100	100
100	106	104	106		101	102
101	106	105	106		102	104
102	106	106	107		103	105
103	107	106	107		104	106
104	107	107	107	102	105	107
105	108	107	108	103	106	108
106	108	108	108	105	107	109
107	109	108	109	106	108	110
108	111	109	110	110	109	110
109	113	110	111	112	110	111
110	114	111	112	113	111	113
111	114	112	113	113	112	114
112	115	113	113	114	113	115
113	115	114	114	115	114	116
114	116	115	115	115	115	117
115	117	116	116	116	116	118
116	118	117	117	117	117	119
117	118	118	118	118	118	119
118	119	118	119	119	119	120
119	120	119	120	119	120	121
120	121	120	121	120	121	122

CAT Composite score

PP score	CL Cauc	CL Min	CL Male	CL Fem	EL Cauc	EL Min
121	122	121	122	121	122	123
122	123	123	123	123	123	123
123	124	124	124	125	124	124
124	125	125	125	126	125	125
125	126	126	126	126	126	126
126	127	128	127	127	126	127
127	128	129	128	128	127	128
128	129	130	130	129	128	129
129	130	131	131	129	129	130
130	131	132	132	130	130	130
131	132	133	133	131	131	131
132	133	133	134	132	132	132
133	134	134	134	133	133	133
134	135	135	135	134	134	134
135	136	136	136	135	135	135
136	137	137	137	137	135	135
137	138	138	138	138	136	
138	139	139	139	139	137	
139	140	141	140	140	137	
140	141	142	141	141	138	
141	142	143	142	142	138	
142	143	144	143	143		
143	144	145	144	144		
144	145	146	145	145		
145	146	147	146	146		
146	147	147	147	147		
147	148	148	148	147		
148	149	149	149	148		
149	150	151	150	149		
150	151	152	151	150		
151	151	153	152	151		
152	152	154	153	152		
153	153	155	153	153		
154	154	156	154	154		
155	155	157	155	155		
156	156	158	156	156		
157	156	159	157	157		
158	157	160	158	158		
159	158	161	158	159		
160	159	162	159	160		
161	160	162	160	162		
162	162	163	161	164		
163	163	165	162	165		
164	164	166	163	166		
165	165	168	164	166		
166	166	170	165	167		
167	167	171	166	168		
168	168		167	169		
169	168		167	169		
170	168		168	169		
171	169		168	170		
172	170		169	170		
173	171		171	171		
174	172			172		